

V803 Centauri: Helium Dwarf Nova Mimicking a WZ Sge-Type Superoutburst

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(Received ; accepted)

Abstract

We observed the long-term behavior of the helium dwarf nova V803 Cen, and clarified the existence of at least two distinct states (a state with 77-d supercycles and a standstill-like state) that interchangeably appeared with a time-scale of 1–2 yr. We also conducted a time-resolved CCD photometry campaign during the bright outburst in 2003 June. The overall appearance of the outburst closely resemble that of the late stage of the 2001 outburst of WZ Sge, consisting of the initial peak stage (superoutburst plateau), the dip, and the oscillating (rebrightening) states. During the initial peak stage, we detected a large-amplitude superhump-type variation with a period of $0.018686(4) \text{ d} = 1614.5(4) \text{ s}$, and during the oscillation stage, we detected variations with a period of $0.018728(2) \text{ d} = 1618.1(2) \text{ s}$. We consider that the former period better represents the superhump period of this system, and the latter periodicity may be better interpreted as arising from late superhumps. The overall picture of the V803 Cen outburst resembles that of a WZ Sge-type outburst, but apparently with a higher mass-transfer rate than in hydrogen-rich WZ Sge-type stars. We suggest that this behavior may be either the result of difficulty in maintaining the hot state in a helium disk, or the effect of an extremely low tidal torque resulting from the extreme mass ratio.

Key words: accretion, accretion disks — stars: dwarf novae — stars: individual (V803 Centauri) — stars: novae, cataclysmic variables — stars: oscillations

1. Introduction

Cataclysmic variables (CVs) are interacting binaries which contain a white dwarf as the mass-accretor. Among CVs, there are a small group containing a helium white dwarf as the mass donor. These systems are either called AM CVn stars (Warner 1995; Solheim 1995) or interacting binary white dwarfs (IBWDs) [see Nelemans et al. (2001b) for the recent progress in confirming the binary nature]. Only a limited number of IBWDs are known at present: AM CVn (Faulkner et al. 1972; Warner, Robinson 1972; Robinson, Faulkner 1975; Solheim et al. 1984; Solheim et al. 1998; Patterson et al. 1992), CR Boo (Nather et al. 1984; Wood et al. 1987; Patterson et al. 1997;

Provencal et al. 1997), V803 Cen (O’Donoghue et al. 1987; O’Donoghue, Kilkenny 1989; O’Donoghue et al. 1990), GP Com (Burbidge, Strittmatter 1971; Warner 1972; Nather et al. 1981), HP Lib (O’Donoghue et al. 1994; Patterson et al. 2002a), CP Eri (Abbott et al. 1992; Groot et al. 2001), KL Dra (Jha et al. 1998; Wood et al. 2002), V396 Hya = CE–315 (Ruiz et al. 2001; Woudt, Warner 2001), ES Cet = KUV 01584–0939 (Warner, Woudt 2002), and SN 2003aw (Woudt, Warner 2003).

The evolution of IBWDs have been widely discussed as descendants from a narrow channel of close binary evolution (cf. Webbink 1984; Tutukov, Yungelson 1996; Nelemans et al. 2001a; Yungelson et al. 2002; Podsiadlowski et al. 2003), particularly in relation to pos-

sible precursors of type-Ia supernovae and unusual objects such as R CrB-type stars, and in relation to recently discovered short-period unusual X-ray sources (Cropper et al. 1998; Ramsay et al. 2000; King et al. 2002; Marsh, Steeghs 2002; Wu et al. 2002; Ramsay et al. 2002a; Israel et al. 2002; Ramsay et al. 2002b; Norton et al. 2002). A recent summary in relation to magnetic CVs can be found in Warner (2003).

The recent discovery of an extremely short-period, hydrogen-rich binary (EI Psc = 1RXS J232953.9+062814) with a massive secondary (Thorstensen et al. 2002) seems to first observationally confirm the existence of the predicted evolutionary path forming IBWDs (Uemura et al. 2002). Together with the discovery of a shortest period CV-type binary (Warner, Woudt 2002), the field of IBWDs provides one of the hottest topics in modern stellar astrophysics. These objects are also considered to be excellent candidates for next generation experiments of directly detecting gravitational wave radiation (Hils, Bender 2000; Strohmayer 2002).

V803 Cen is one of the first identified IBWDs (O'Donoghue et al. 1987; O'Donoghue, Kilkenny 1989), which had been originally considered to be an R CrB-type hydrogen-deficient variable star. It took, however, rather long time before the dwarf nova-type behavior of this object was established. Warner (1995) originally considered that this object may be a helium analog of a VY Scl-type CV with occasional fadings (cf. Warner, van Citters 1974; Garnavich, Szkody 1988; Greiner 1998; Leach et al. 1999; Kato et al. 2002b). The “low state” description (O'Donoghue et al. 1990) of the object's state exactly follows the notation in VY Scl-type CVs. It was only after the “northern counterpart” CR Boo was found to more or less display common characteristics with the hydrogen-rich dwarf novae (Patterson et al. 1997).

The assertion of CR Boo as being a “dwarf nova” in Patterson et al. (1997) was, however, later found to be an incomplete description of the behavior what this object displays. Kato et al. (2000a) revealed that the CR Boo is actually a helium counterpart of an SU UMa-type dwarf nova with a very short (46.3 d) supercycle, corresponding to ER UMa stars in hydrogen-rich CVs (Kato, Kunjaya 1995; Robertson et al. 1995; Misselt, Shafter 1995; Nogami et al. 1995). The variations Patterson et al. (1997) referred to as dwarf nova-type outbursts were actually more unusual short-term oscillations seen in its “standstill-like” states (Kato et al. 2000a; Kato et al. 2001b). The true dwarf nova-type character of CR Boo manifests itself more in the 46.3-d supercycle, which agrees quite well with the theoretical interpretation of the disk-instabilities in a helium accretion disk (Tsugawa, Osaki 1997). Kato et al. (2001c) suggested the possibility that the short-term oscillations reported in Patterson et al. (1997) may reflect more or less stabilized thermal disk-instability.

Following this progress in CR Boo, the dwarf nova-type nature of V803 Cen was finally elucidated by the following two works: Patterson et al. (2000) primarily reported on the presence of superhumps and oscillating

Table 1. Observers and Equipment.

Observer	Telescope*	CCD	Software
Butterworth	20-cm SCT	ST-7E	AIP4Win
Monard	30-cm SCT	ST-7E	AIP4Win
Bolt	25-cm SCT	ST-7	MuniPack
Richards	18-cm refractor	ST-7E	AIP4Win

* SCT = Schmidt-Cassegrain telescope.

states, and Kato et al. (2000b) reported on the detection of the supercycle almost identical with that of CR Boo. The oscillating state in Patterson et al. (2000) is likely a “standstill” (Kato et al. 2001b), which is characteristics of Z Cam-type dwarf novae (see e.g. Hellier 2001a Sect. 5.4; see also Warner, van Citters 1974; Meyer, Meyer-Hofmeister 1983; Oppenheimer et al. 1998). Since there is no known hydrogen-rich object which shows both superoutbursts and standstills, this feature of CR Boo and V803 Cen is quite challenging to dwarf nova theories. Furthermore, Kato et al. (2001a) reported a sudden dramatic change in the supercycle in CR Boo, which is also unexpected from the analogy with hydrogen-rich CVs. Both aspects will be discussed in later sections.

2. Observation

The long-term visual observations were mostly undertaken by Rod Stubbings, supplemented from reports to VSNET (Kato et al. 2003d)¹. The light curve is shown in Figure 1. This figure corresponds to figure 1 (CR Boo) of Kato et al. (2001a).

Upon the detection of the 2003 June bright outburst by Rod Stubbings (visual magnitude 12.6 on June 4.476 UT, vsnet-campaign-dn 3735, see also (<http://www.kusastro.kyoto-u.ac.jp/vsnet/DNe/v803cen0306.html>)), we initiated CCD photometric campaign through the VSNET Collaboration.

The CCD observations were performed unfiltered. Observers and equipment are summarized in Table 1. Table 2 summarizes the log of observations. Butterworth and Richards used GSC 7795.1030 for the primary comparison star, whose constancy during the observation was confirmed by the comparison with GSC 7795.1402. Monard and Bolt used the primary comparison star GSC 7795.184 and the check star GSC 7795.1030. Systematic corrections to individual observers were determined both by calculating mean differences of comparison and check stars, and by maximizing the correlation between simultaneous observations. All observations were thus converted to a common scale (system close to R_c) relative to GSC 7795.184. Errors of single measurements were typically less than 0.01–0.03 mag unless otherwise specified.

Barycentric corrections to the observed times were applied before the following analysis.

¹ (<http://www.kusastro.kyoto-u.ac.jp/vsnet/>)

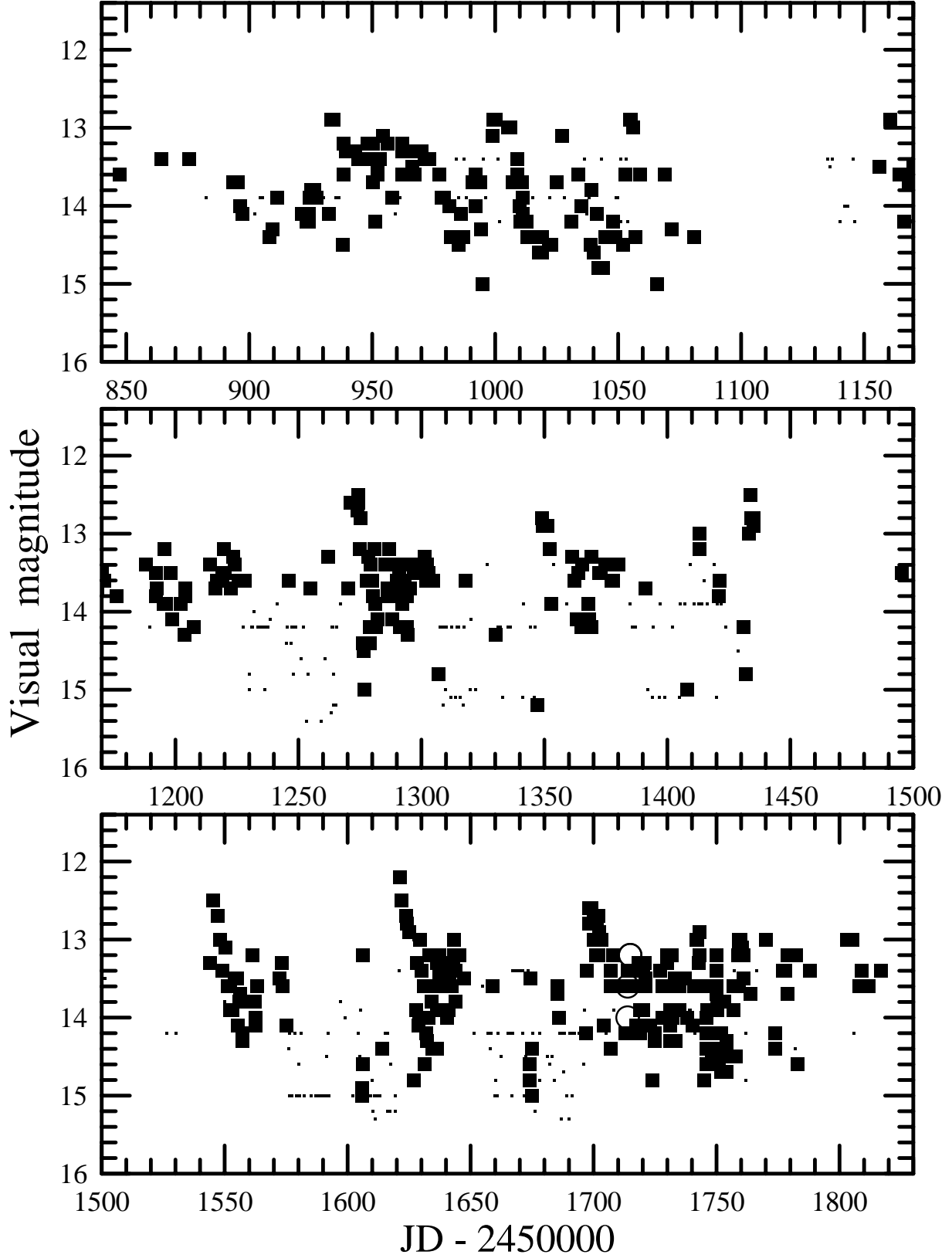


Fig. 1. Long-term light curve of V803 Cen. The large and small filled squares represent positive and negative (upper limit) visual observations. The open circles and open squares represent snapshot V -band CCD and unfiltered CCD (zero point adjusted to R_c system) observations. Please note that the true quiescence of V803 Cen is below this figure ($V \sim 16.8$ – 17.2). A few CCD observations close to the quiescent magnitude were not shown in order to better display the outburst behavior.

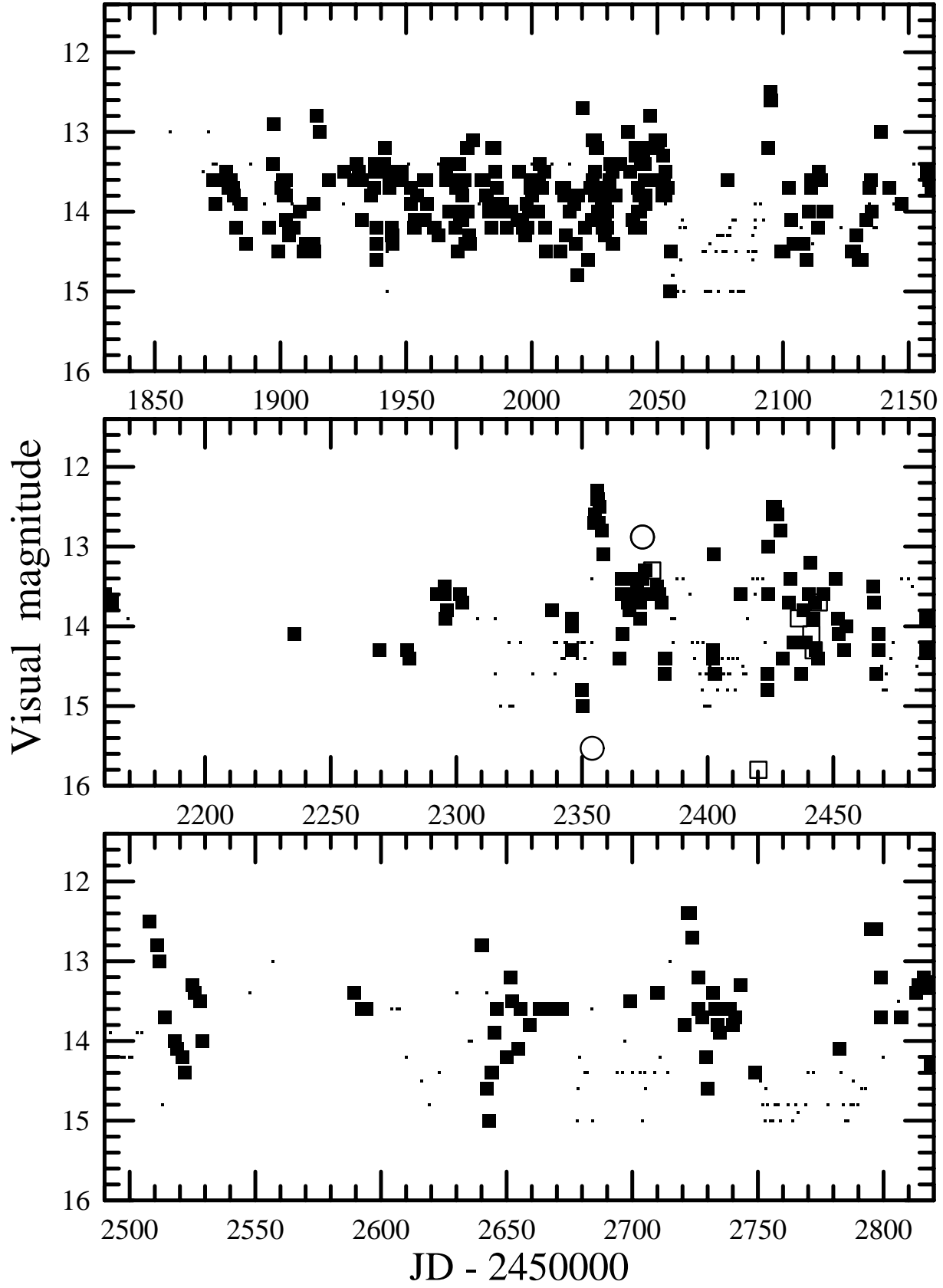


Fig. 1. (continued)

Table 2. Journal of CCD photometry.

	Date		Start–End*	Exp(s)	<i>N</i>	Observer
2003	June	6	52796.860–52797.072	60	227	Butterworth
		7	52797.860–52798.079	60	236	Butterworth
		7	52798.251–52798.473	15	654	Monard
		8	52798.934–52799.068	60	149	Butterworth
		8	52798.966–52799.166	45	336	Bolt
		8	52799.235–52799.492	45	267	Monard
		9	52800.183–52800.324	45	162	Monard
		10	52801.057–52801.125	180	32	Richards
		10	52801.193–52801.508	45	441	Monard
		11	52802.186–52802.402	45	312	Monard
		12	52802.972–52803.061	60	116	Bolt
		12	52803.175–52803.427	45	308	Monard
		13	52803.981–52804.145	60	214	Bolt
		13	52804.177–52804.499	45	456	Monard
		14	52804.938–52805.199	60	340	Bolt
		14	52805.183–52805.413	45	326	Monard
		15	52806.230–52806.482	45	358	Monard
		16	52806.934–52806.985	60	66	Richards
		16	52807.259–52807.466	45	289	Monard

* BJD–2400000.

3. Results

3.1. Long-Term Light Curve

As shown in Figure 1, V803 Cen displays at least two different states of outburst activity. The intervals JD 2451250–2451700 and JD 2452350–2452820 (possibly since JD 2452090) are characterized by the presence of interchangeably occurring bright outbursts and a faint phase, which is sometimes interrupted by short faint outbursts. This state is very reminiscent of the 46.3-d supercycle observed in CR Boo (Kato et al. 2000a). This state was identified by Kato et al. (2000b) to be 77-d supercycle with a superoutburst duty cycle of ~ 0.4 . The other state covers the interval JD 2451710–2452050 (although there is an unavoidable seasonal observational gap present, there was no clear indication of a state change during this interval). During this state, V803 Cen was mostly observed between 13.0 and 14.5 mag. Patterson et al. (2000) recorded a similar state in 1997 April (outside this long-term light curve), and referred to this as a “cycling state” showing ~ 1.0 mag variations with a period of 22 ± 1 hr. When compared to the 77-d supercycle, this state more looks like a standstill seen in Z Cam-type (hydrogen-rich) dwarf novae (Kato et al. 2001b), although no such cycling variation was observed during Z Cam-type stars.

The behavior for the interval JD 2450930–2451070 was rather unusual. During this period, the first outburst was longer than the typical ones regularly seen in the 77-d supercycle, and there was an indication of shortening of outburst intervals to 25–30 d in the later part. There is some indication that a similar state was present between JD 2451150 and 2451230. This state may be something intermediate between the state with regular 77-d super-

cycles and the standstill-like state, as inferred from the duration or duty cycle of the outbursts. This state may be analogous to the transient appearance of a 14.7-d period in CR Boo (Kato et al. 2001a).

3.2. Overall Light Curve of the 2003 June Outburst

Figure 2 shows the overall unfiltered CCD light curve of the 2003 June outburst drawn from the data in Table 2. The CCD observations started 1.9 d after the initial outburst detection. Visual observations confirmed that the object remained bright until the initial CCD observation. The object remained at bright maximum for ~ 3 d, and suddenly started fading (JD 2452799, 2003 June 8). After reaching a deep transient minimum (or the “dip”, ~ 2.5 mag fainter than the maximum) on JD 2452800 (June 9), the object brightened again and entered an oscillating state. This oscillating state is similar to the “cycling state” described by Patterson et al. (2000), but is apparently different in that the present state was preceded by the sequence of an initial outburst peak and a subsequent transient “dip”. During this state, the mean magnitude gradually faded at a rate of ~ 0.1 mag d^{-1} . This sequence of the outburst activity composed of an initial bright state, a transient fading (dip) and short-period oscillating state reminds us of the similar sequence recorded in the 2001 superoutburst of WZ Sge (Ishioka et al. 2002; Patterson et al. 2002b; see also <http://www.kusastro.kyoto-u.ac.jp/vsnet/DNe/wzsge01.html>) during its dip-rebrightening phase (Osaki, Meyer 2003). This sequence, composed of initial short peak brightness, followed by a dip-like fading, and a long-lasting probably oscillating phase is commonly seen in visual observations of other

superoutbursts² of V803 Cen (Figure 1). This feature was documented as “damping oscillations” in Kato et al. (2000b), although the present observation far better clarified the detailed behavior at this stage of a superoutburst. Please note that this feature is also common to CR Boo (Kato et al. 2000a).

3.3. Initial Peak and Superhumps

During the first three days of the superoutburst, the object showed an almost linear, slow decay. Such a slow variation was not observed during the subsequent stages. The mean fading rate of this stage was $0.16 \pm 0.01 \text{ mag d}^{-1}$. This value is similar to the mean fading rates of the superoutburst plateau stages of hydrogen-rich SU UMa-type dwarf novae (cf. Warner 1985; Patterson et al. 1993; Kato et al. 2002c), and is consistent with the model calculation of a superoutburst in a helium accretion disk (Tsugawa, Osaki 1997).

During this stage, clear oscillations were observed (Figure 3). A period analysis of the data during the initial peak stage with the Phase Dispersion Minimization (PDM: Stellingwerf 1978), after removing the linear trend, yielded a period of $0.018686(4) \text{ d} = 1614.5(4) \text{ s}$ (Figure 4). The error of the period was estimated using the Lafler–Kinman class of methods, as applied by Fernie (1989). This period agrees with the 1608–1620 s period reported as the superhump period (O’Donoghue et al. 1990; Patterson et al. 2000).³ The firm presence of the superhumps as well as the slowly fading phase further confirmed the superoutburst nature of this initial peak.

Figure 5 shows the evolution of the superhump profile during the initial peak phase. The three panels correspond to the three segments displayed in Figure 3. The superhump profile was initially triangular, with a rapid rise and a slower decline, which is characteristic of fully developed (hydrogen-rich) SU UMa-type superhumps (Vogt 1980; Warner 1985; see also O’Donoghue 1995, Simpson, Wood 1998 and Wood, Simpson 1995 for more discussion of superhumps in IBWDs). One day later ($\sim 3 \text{ d}$ after the initial detection of the outburst), a secondary maximum appeared in the superhump profile, similar to secondary maxima in some (hydrogen-rich) SU UMa-type superhumps (cf. Udalski 1990; Kato et al. 1992; Kato et al. 2003a). This feature usually appears at the late stage of a superoutburst, and is possibly related to “late superhumps” (Haefner et al. 1979; Vogt 1983; van der Woerd et al. 1988; Hessman et al. 1992), which are known to have similar periods as ordinary superhumps, but have phases ~ 0.5 different from those of ordinary superhumps. The late appearance of the secondary maximum in V803 Cen follows the “textbook” evolution of superhumps of

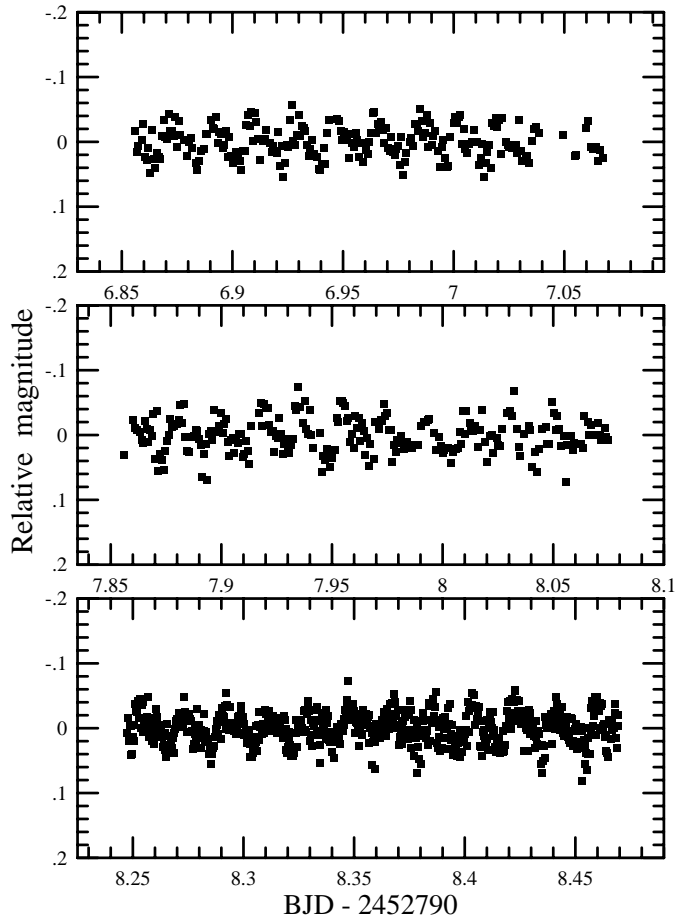


Fig. 3. Superhumps observed during the initial brightness peak of the superoutburst. The slow fading trends were subtracted from the observations. The errors of individual observations are less than 0.02 mag.

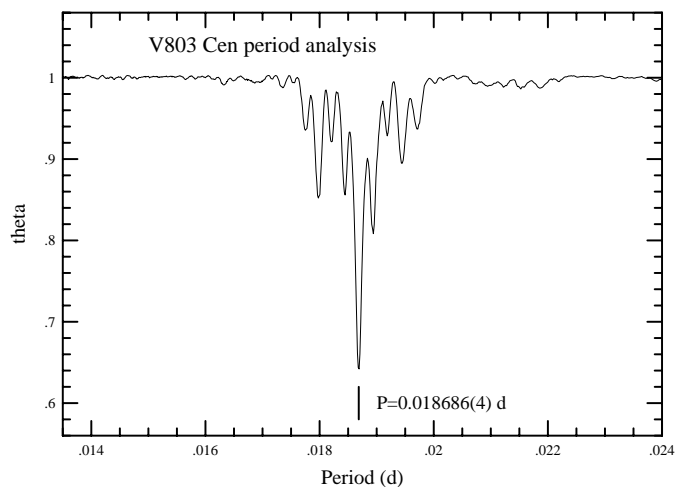


Fig. 4. Period analysis of the superhumps observed during the initial brightness peak of the superoutburst.

² We refer to bright outbursts in the 77-d supercycles as superoutbursts.

³ Patterson et al. (2002a) selected in a table the orbital and superhump periods of $1612.0(5) \text{ s}$ and $1618.3(8) \text{ s}$, respectively, from various source of the literature. Because of the relatively small fractional superhump excess inferred from these periods, and because of the claimed instability of the periods (Patterson et al. 2000), these values should better be treated as tentative identifications.

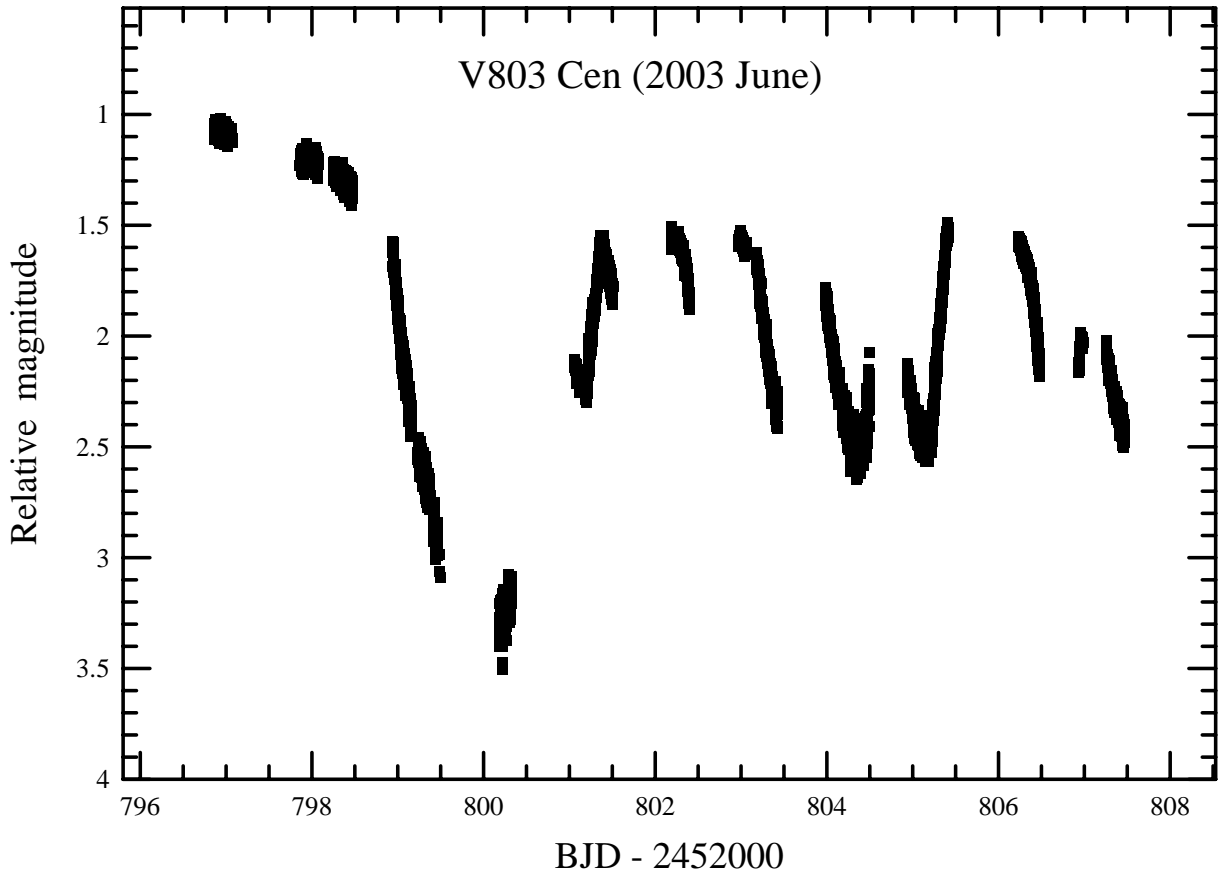


Fig. 2. Unfiltered CCD light curve (system close to R_c) of V803 Cen during the 2003 June outburst. The magnitudes are given relative to GSC 7795.184 (USNO B2.0 mean red magnitude 11.7).

hydrogen-rich SU UMa-type dwarf novae. The mean superhump profiles displayed in O’Donoghue et al. (1987); O’Donoghue, Kilkenny 1989; O’Donoghue et al. 1990; Patterson et al. (2000) more or less showed this secondary maximum, indicating that the “pure” triangular superhump profile is only briefly seen during the early stage of a superoutburst.

3.4. Rapidly Fading Stage

Immediately following the initial peak stage, the object started to fade very rapidly. Figure 6 shows the enlargement of the rapid decline phase. The mean rates of declines in segments (1), (2) and (3) are 4.3, 2.6 and 1.9 mag d⁻¹, respectively. Even during this rapid decline phase, oscillations were clearly present, as is already evident in Figure 6. Figure 7 shows the phase-averaged profiles within the respective segments in Figure 6 with the assumption of a constant period of 0.018686 d (subsection 3.3).

Assuming the 0.018686-d period, the second maximum of the superhump (subsection 3.3) was dominant during the earliest stage of the decline (segment 1). However the initial peak became stronger as the object faded further (segments 2 and 3).

Alternately, we can interpret the progressive variation of the hump phases as the result of the change in domi-

nant period. A PDM analysis of this rapid fading stage (combined set of three segments) has yielded a period of 0.01845(2) d = 1594(2) s (Figure 8). This period is close to the period (cf. Patterson et al. 2000) which may be related to the orbital period. If this period is the orbital period, the fractional superhump excess becomes $1.3 \pm 0.1\%$. The exact identification of the period, however, should await further detailed observation fully covering the initial peak through rapid fading and later stages, and examination of the coherence of the signal over multiple outbursts.

3.5. Oscillating Stage

Following the dip, the object rebrightened into the oscillating stage, which is remarkably similar to the *rebrightening phase* (Osaki, Meyer 2003) of the 2001 outburst of WZ Sge (Ishioka et al. 2002; Patterson et al. 2002b). During this stage, the object showed ~ 1 mag oscillations with periods of 0.8–1.0 d. We did not attempt to make an average period of these oscillations, because the waveforms were apparently variable and a number of maxima fell within the gaps of observations.

We first prewhitened these oscillations, by subtracting overall trends with time scales longer than 0.07 d (for slow modulations; sharp “kinks” in the light curves were removed by dividing the light curve into smaller segments) for the interval June 9–17. A PDM period analysis of the

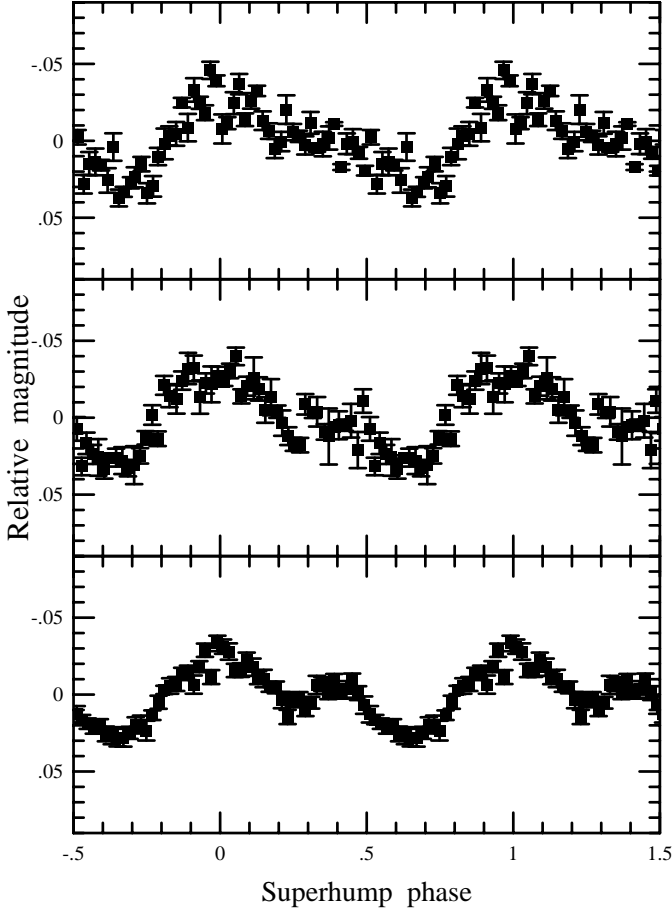


Fig. 5. Mean superhump profiles. The three panels correspond to the three segments displayed in Figure 3. The phase zero corresponds to BJD 2452789.9950.

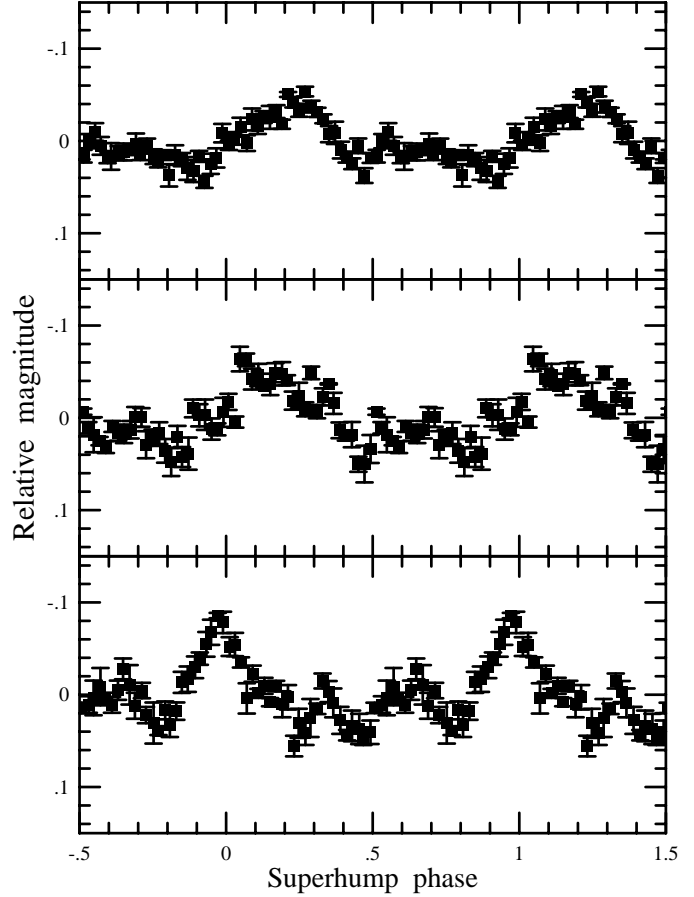


Fig. 7. Mean (super)hump profiles during the rapid decline phase assuming the constant period of 0.018686 d. The three panels correspond to the segments marked in Figure 6. The definition of the phase zero is identical with Figure 5.

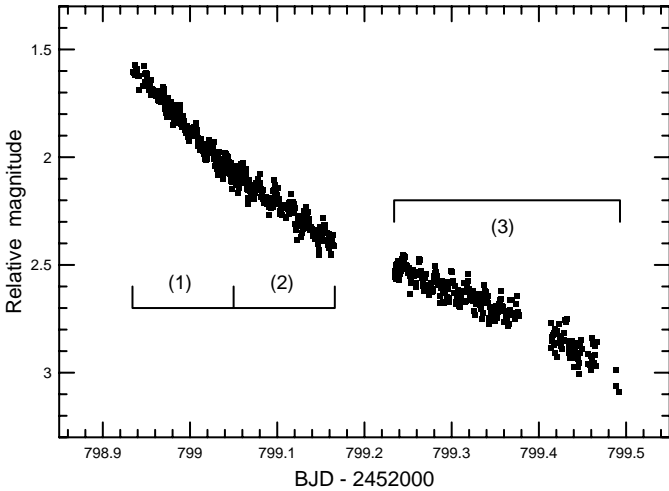


Fig. 6. Enlargement of the rapid decline from the initial peak. The segments (1),(2) and (3) correspond to the panels in Figure 7.

entire oscillating stage yielded a period of 0.018728(2) d = 1618.1(2) s (Figure 9). The significance of this period is 92%. The mean light curve at this period has a rather complex structure, with a second maximum around phase 0.7. Figure 10 presents the profile of the 0.018728-d period (see table 3 for the definition of the segments). These profiles indicate that this periodicity is variable in amplitude and in waveform, although no clear evidence of a systematic phase shift of the peaks was observed. The signal became weaker when the object is bright (segments 4–7, 12), and became strongest when the object is fainter (segments 3, 10, 11, 14).

4. Discussion

4.1. Overall Outburst Light Curve

As mentioned in subsection 3.2, the present outburst, and possibly past bright outbursts, are composed of a sequence of an initial bright state, a transient fading (dip) and short-period oscillating state. This sequence is very similar to the 2001 superoutburst of WZ Sge (Ishioaka et al. 2002; Patterson et al. 2002b) during its dip–

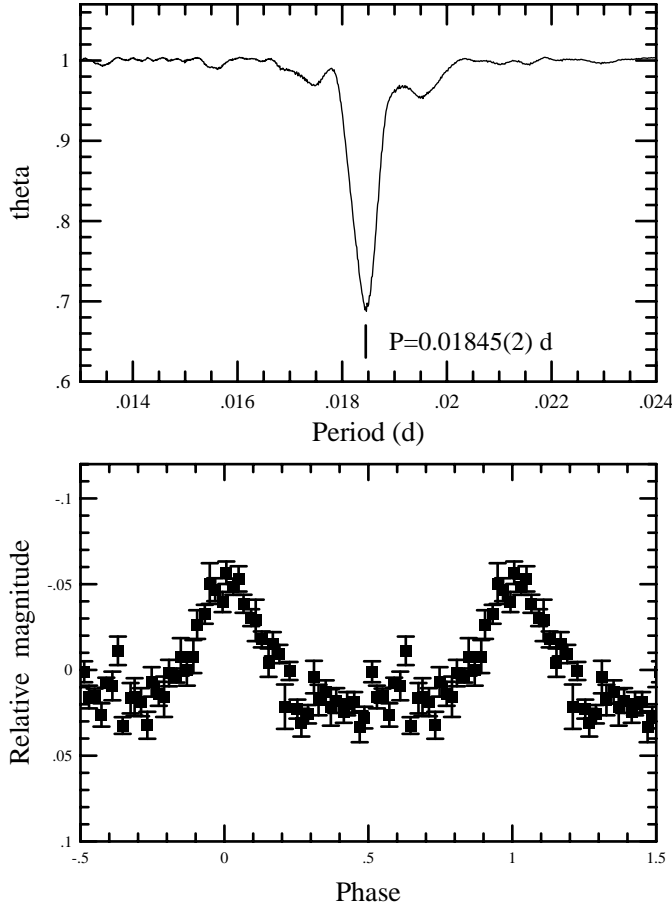


Fig. 8. (Upper:) Period analysis of the rapid decline phase from the initial peak. (Lower:) Mean profile phase-averaged at the best period.

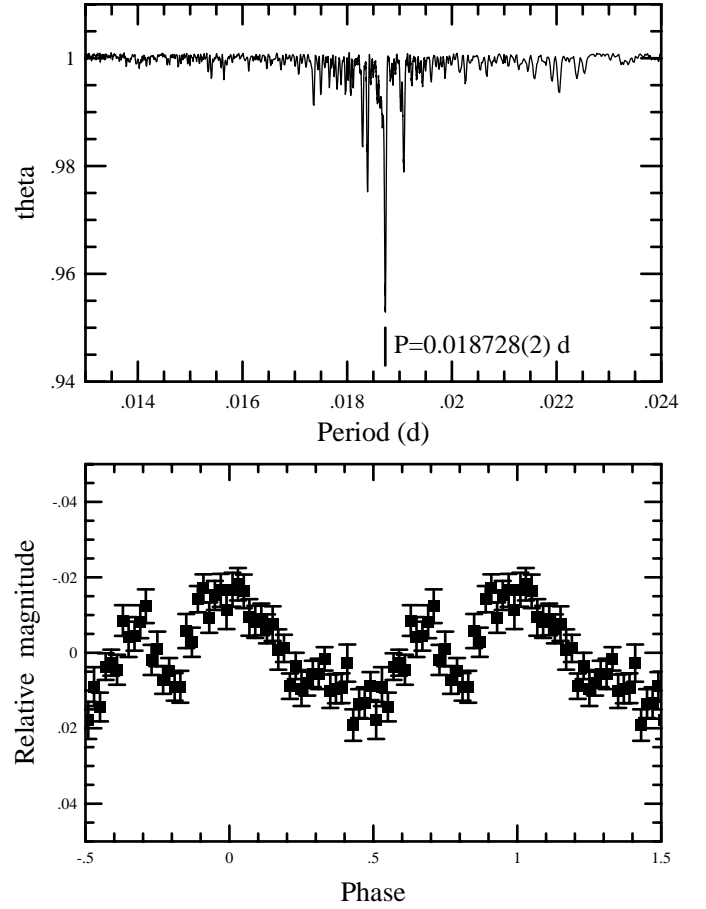


Fig. 9. (Upper:) Period analysis of the short-period variation during the oscillating stage. (Lower:) Mean profile phase-averaged at the best period.

Table 3. Segments of the oscillating stage used in Figure 10.

Segment	BJD range*	Mag [†]	State
1	0.186–0.324	3.3–3.1	slow rise
2	1.057–1.125	2.1–2.2	slow fade
3	1.193–1.369	2.2–1.6	rising
4	1.370–1.508	1.6–1.8	slow fade
5	2.186–2.309	1.5–1.6	near maximum
6	2.310–2.379	1.6–1.8	slow fade
7	2.972–3.010	1.5–1.6	near maximum
8	3.175–3.320	1.6–2.1	fading
9	3.981–4.145	1.8–2.3	fading
10	4.177–4.300	2.3–2.5	slow fade
11	4.938–5.050	2.1–2.4	slow fade
12	6.230–6.370	1.5–1.7	slow fade
13	6.934–6.960	2.1–2.0	slow rise
14	7.259–7.350	2.0–2.3	fading

* BJD–2452800.

† Magnitude relative to GSC 7795.184.

rebrightening phase (20–45 d after the maximum: Osaki, Meyer 2003). A comparison of the light curves is given in Figure 11. The light curve of V803 Cen is repeated here for clarity. In V803 Cen, however, the initial superoutburst phase is much shorter than that of WZ Sge.

In WZ Sge, this “rebrightening” phenomenon is interpreted as a recurring thermal instability (normal outbursts) in the remaining accretion disk (Osaki, Meyer 2003; see also Osaki et al. 1997, Osaki et al. 2001 for the supposed basic mechanism). In WZ Sge, this recurrent rebrightening is considered to be maintained by a mass supply from the outer mass reservoir (see Osaki, Meyer 2003; see also Kato et al. 1998 and Hellier 2001b for the basic idea in SU UMa-type dwarf novae). As shown in Osaki (1995b) and Osaki, Meyer (2003), a natural explanation of these special features in WZ Sge-type stars would require an extremely low quiescent viscosity, which is probably a result of the quenching of the MHD turbulence under the condition of the low magnetic Reynolds numbers in a cold quiescent accretion disk of a WZ Sge-type star (Gammie, Menou 1998).

In V803 Cen, however, the large mass reservoir is not naturally expected as in WZ Sge, since the object has

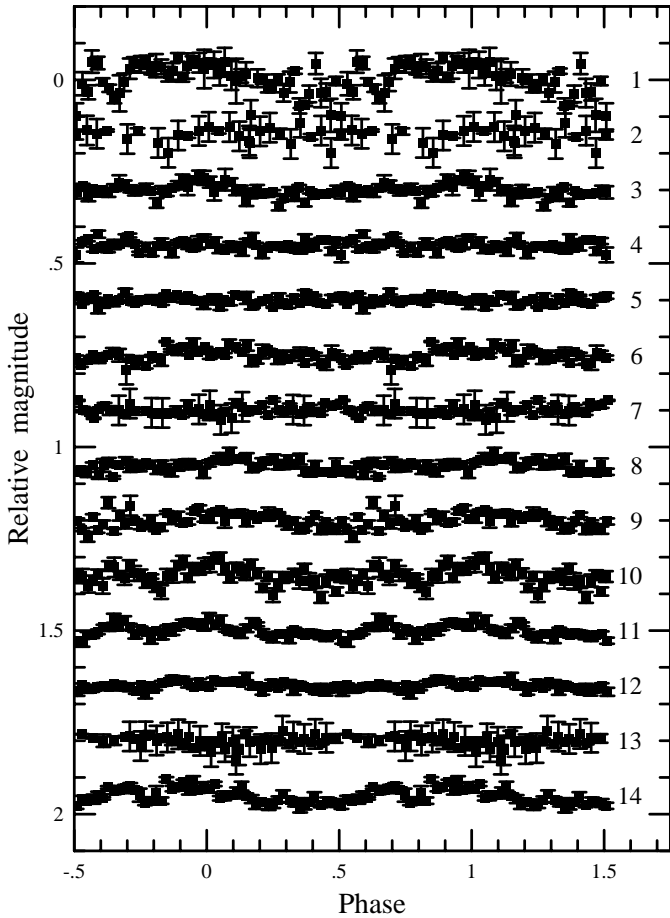


Fig. 10. Profiles of 0.018728-d periodicity during the oscillating stage. The numbers in the right side represent segment numbers listed in table 3.

a short (~ 77 d) supercycle, and is expected to have a high mass-transfer rate (\dot{M}) close to thermal stability (Tsugawa, Osaki 1997), which probably does not satisfy the necessary condition in (Osaki 1995b).

The unusual outburst behavior of V803 Cen (and possibly CR Boo), in turn, may be the result of an extremely small mass ratios ($q = M_2/M_1$, see e.g. Patterson et al. 2002a) and the helium disk. Considering the extremely short duration [compared to the simulation by Tsugawa, Osaki (1997), who assumed that the superoutburst is automatically maintained while the tidal torque is above a certain value] of the initial superoutburst, the superoutbursting state of the helium accretion disk in V803 Cen may be more difficult to maintain, thereby resulting in an early quenching of the superoutburst. This difficulty is to be expected since the helium disk requires a higher temperature ($T \sim 15000$ K) to maintain the high state (Smak 1983; Cannizzo 1984). This early quenching process leaves a substantial amount of disk matter, which acts similarly as the outer mass reservoir in WZ Sge.

Alternately, the low tidal torque arising from a small q may be responsible for the short superoutbursting state. This explanation was originally proposed by Nogami

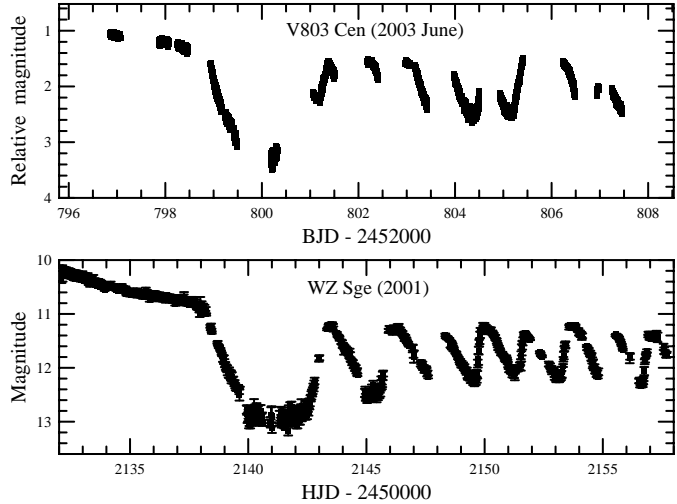


Fig. 11. Comparison of light curves of V803 Cen (2003 June) and WZ Sge (2001). The WZ Sge observations are from Ishioka et al. (2002) and R. Ishioka et al. in preparation. The “dip” we refer to in WZ Sge corresponds to the period HJD 2452139–2452143.

et al. (1995) to explain the unusual short superoutbursts in RZ LMi (an extreme ER UMa star, see Osaki 1995c) [see also Hellier (2001b) for the application to other ER UMa stars]. The unusual outburst behavior of V803 Cen may provide an important link between helium dwarf novae and unusual hydrogen-rich systems such as ER UMa stars and WZ Sge-type stars.

4.2. Standstills and Occasional Shortening of Supercycles

As described in subsection 3.1, both V803 Cen and CR Boo show occasional “standstill”-like states and occasional shortening of the supercycles (Kato et al. 2001a). Both phenomena are difficult to understand in hydrogen-rich SU UMa-type dwarf novae.

The presence of standstills indicates that the accretion disk is somehow maintained in the thermally stable state (Meyer, Meyer-Hofmeister 1983), probably by a varying mass-transfer in Z Cam-type dwarf novae. This mechanism would be, however, less effective in hydrogen-rich SU UMa-type dwarf novae, since the long-term magnetic activity of the secondary star, probably responsible for the long-term changes in \dot{M} , is expected to be weaker in a fully convective secondary of an SU UMa-type dwarf nova.

There recently exists, however, some observational evidence for the long-term \dot{M} change even in SU UMa-type dwarf novae (Kato 2001; other reported long-term changes of outburst parameters in SU UMa-type including Kato 2002; Kato et al. 2002a; Nogami et al. 2003a; Nogami et al. 2003b; Kato et al. 2003b may reflect similar activity). The long-term \dot{M} change may be equally present in helium dwarf novae. If this is the case, the typical time scale (1–2 yr) of the interchanges between outbursting and standstill states is expected to represent

the typical activity time scale in a helium white dwarf, although the mechanism for such an activity has not been clarified.

The standstills in V803 Cen and CR Boo are not true standstills comparable to those of Z Cam-type dwarf novae without detectable outburst activities. The oscillation periods (0.8–1.0 d) during these standstills are too short for usual full-disk outbursts (Tsugawa, Osaki 1997), but naturally reflect some sort of thermal disk-instability. The presence of thermal instability may also arise from the difficulty in fully maintaining the hot state in a helium disk. The clarification of the exact mechanism, however, would require future full-disk calculations of a helium accretion disk.

The occasional shortening of the supercycles is also difficult to explain, because high \dot{M} produces longer duration superoutbursts, resulting in longer duration supercycles in hydrogen-rich systems (Osaki 1995a). This difficulty, however, may be avoided by early quenching of the superoutbursting state in a helium disk, or by an extremely small q .

4.3. Superhump Period

The exact identification of the superhump and orbital periods in helium dwarf novae are often complex, particularly when there are large-amplitude outbursts.

During the oscillating state, we obtained a period of 0.018728(2) d = 1618.1(2) s, which is close to what Patterson et al. (2002a) identified as the superhump period. However, since a large fraction of the observation by Patterson et al. (2000) was performed during the oscillating state (likely during a “standstill”), this identification needs to be treated with caution. During the initial peak state (corresponding to the superoutburst plateau in a hydrogen-rich SU UMa-type dwarf nova) we obtained a slightly different period of 0.018686(4) d = 1614.5(4) s. Based on the analogy with hydrogen-rich SU UMa-type dwarf novae, the latter period is better expected to reflect the true superhump period (Vogt 1980; Warner 1985).

If the currently observed oscillating stage indeed corresponds to the “rebrightening phase” in WZ Sge (subsection 4.1), the periodic variations observed during this state may represent late superhumps (e.g. Vogt 1983). Since the period of late superhumps (especially long-lasting ones as in WZ Sge-type dwarf novae) is found to be slightly, and often discontinuously, longer than the main superhump period (e.g. Patterson et al. 1998; Kato et al. 2003c; R. Ishioka et al. in preparation), this slightly longer period can be interpreted as the period of late superhumps, and the true superhump period is 0.018686(4) d = 1614.5(4) s. The relation between the signal amplitude and the system brightness (subsection 3.5) is also identical with the late superhumps in WZ Sge-type dwarf novae (Kato et al. 1997; R. Ishioka et al. in preparation), which also supports the interpretation of the longer signal as late superhumps.⁴

⁴ Ideally, it is preferable to demonstrate the presence of ~ 0.5 phase change between the main outburst and the oscillating

From the present observation, we have not been able to find conclusive evidence for the orbital period, although a shorter period than the superhump period may have been transiently recorded (subsection 3.3). Correct identification of the true orbital and superhump periods should await further long-baseline observations.

5. Summary

We observed long-term behavior of V803 Cen, and confirmed that it displays at least two different states of outburst activity: (1) state with outbursts with a supercycle of ~ 77 d, which is very reminiscent of the 46.3-d supercycle in CR Boo, and (2) “standstill”-like state with oscillations with a time-scale of ~ 1 d. These two state interchangeably appear with a time-scale of 1–2 yr. During the bright outburst in 2003 June, we conducted a time-resolved CCD photometry campaign. This outburst was composed of distinct states: (1) initial peak lasting for ~ 3 d with a slow linear decline, (2) a “dip”-like transient fading, (3) oscillating (or rebrightening) stage which resembles the “standstill”-like state but with a gradual overall fading. The overall appearance of the outburst closely resembles that of the late stage of the 2001 outburst of WZ Sge. During the initial peak stage, we detected large-amplitude superhump-type variation with a period of 0.018686(4) d = 1614.5(4) s, and during the oscillation stage, we detected variations with a period of 0.018728(2) d = 1618.1(2) s but with a smaller and variable amplitude. We consider that the former period better represents the superhump period of this system, while the latter period may be that of late superhumps. The overall picture of the V803 Cen outburst resembles that of a WZ Sge-type outburst, but apparently with a higher mass-transfer rate than in WZ Sge-type stars. We suggest that this behavior may be either the result of difficulty in maintaining the hot state in a helium disk or the effect of an extremely low tidal torque resulting from the extreme mass ratio.

The authors are grateful to observers, especially to A. Pearce and P. Williams who reported many observations to VSNET. This work is partly supported by a grant-in-aid (13640239, 15037205) from the Japanese Ministry of Education, Culture, Sports, Science and Technology. The CCD operation of the Bronberg Observatory is partly sponsored by the Center for Backyard Astrophysics. The CCD operation by Peter Nelson is on loan from the AAVSO, funded by the Curry Foundation. This research has made use of the Vizier catalogue access tool. We are grateful to R. Ishioka for providing the WZ Sge observations prior to publication.

stage. This was not fulfilled because of the ambiguity of cycle counts during the “dip” phase (even the slight difference between the two representative periods, 0.01845 d and 0.018728 d as described in the text, already introduces more than 0.5 phase uncertainty during the 1-d observational gap in the dip stage), and the overall weakness of the signal during the oscillating stage (Figure 10). Confirmation of the phase jump should await a future continuous observation.

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